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RESULTS OF PENETRATION TESTS OF HEAT AMMUNITION CONTAINING OCTOL BURSTING CHARGES (U)

J. DONALD HOPPER

JUNE 1957

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SAMUEL FELTMAN AMMUNITION LABORATORIES
PICATINNY ARSENAL
DOVER, N. J.

ORDNANCE PROJECT TA3-5000D

DEPT. OF THE ARMY PROJECT 5A04-10-006

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RESULTS OF PENETRATION TESTS OF HEAT AMMUNITION CONTAINING OCTOL BURSTING CHARGES (U)

by

J. Donald Hopper

June 1957

Picatinny Arsenal
Daver, N. J.

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Technical Report 2439

Ordnance Project TA3-5000D

Dept of the Army Pproject 5A04-10-006

Approved

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OBJECT

To evaluate cast octol bursting charges for HEAT ammunition.

SUMMARY

This report presents the data obtained in eight series of static firing tests in which various HEAT shell, grenades, and rocket heads loaded with mixtures of HMX and TNT, referred to as octols, were compared with similar shell, grenades, and heads loaded with Composition B with respect to effectiveness in penetrating steel targets. The octols tested were 70/30 HMX/TNT and 75/25 HMX/TNT.

The performance of 70/30 octol, judged on the basis of maximum and average penetration data, exceeded that of Composition B in 7 of the 7 series of tests in which these explosives were compared. The improvement ranged from 4.4% to 19.9% (calculated from the average penetration data). The performance of 75/25 octol exceeded that of Composition B in all but one of the 7 series in which these explosives were compared. The improvement ranged from 4.4% to 11.1%.

The performance of 70/30 octol exceeded that of 75/25 octol in 4 of the 6 series in which these explosives were compared. In one of the four, 70/30 octol was about 8% more effective and 75/25 octol 2% less effective than Composition B. This anomalous

result is attributed to imperfections in the 75/25 octol bursting charges. Difficulty was experienced in loading the heads with 75/25 octol, since the 75/25 octol available at the time was abnormally viscous in the molten state. Although it was found that 75/25 octol can be loaded into most HEAT ammunition without serious difficulty if the viscosity of the explosive is properly controlled, less difficulty was experienced in producing good quality bursting charges from 70/30 octol than from 75/25 octol because the 70/30 octol was less viscous. This is reflected in the apparent superiority in performance of 70/30 octol over 75/25 octol in the four series of tests.

Comparison of the results of the first series of tests with those of the third series shows that a large improvement in the ability of the 3.5-inch T205 rocket head to penetrate steel was obtained when 75/25 octol bursting charges were used in combination with "double-angle," or trumpet-shaped, charge liners in place of Composition B charges with ordinary conical liners. Judged on the basis of the average penetration values, 13.98 and 20.75 inches respectively, the improvement was nearly 50%.

CONCLUSIONS

Replacement of Composition B with 70/30 or 75/25 octol as the explosive filler for shaped charge type ammunition should result in a substantial improvement in the potential terminal effectiveness

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of this type of ammunition. The depth to which non-rotated HEAT ammunition can penetrate steel targets can be increased at least 10% by such direct substitution of explosives.

Use of octol bursting charges in conjunction with "double-angle," or trumpet-shaped, charge liners will impart to HEAT ammunition the ability to penetrate much deeper into steel targets than can similar ammunition containing ordinary conical liners and Composition B charges or conical liners and octol charges.

Although 75/25 octol is potentially more effective than 70/30 octol, the lower viscosity of 70/30 octol in the molten state facilitates the attainment of high quality in loading this explosive to such an extent that in some ammunition designs 70/30 octol bursting charges will perform as well as or better than 75/25 octol charges. For this reason 70/30 octol should be used in preference to 75/25 octol in HEAT type ammunition whenever the metal parts design makes it difficult to attain high quality in loading the explosive charge.

RECOMMENDATIONS

It is recommended that (1) 75/25 octol, or 70/30 octol be used in place of Composition B for the explosive charge in the warheads of guided missiles designed to utilize the shaped charge principle, such as the Dart and the Lacrosse; (2) consideration be given to using 70/30 octol bursting charges in

each new item of HEAT ammunition being developed and to replacing Composition B with 70/30 octol in existing designs of HEAT ammunition wherever the expected improvement in performance warrants the slightly greater per round cost; and (3) development of 75/25 octol of substantially lower viscosity than that now available be undertaken, and that methods for loading the improved product be studied to develop procedures for loading HEAT ammunition which will yield bursting charges of excellent quality.

INTRODUCTION

1. The first definite indication that the performance of HEAT ammunition can be improved by using castable HMX/TNT mixtures, referred to in this report as octols, for the bursting charge was obtained here in 1952 in exploratory static firing tests of four 3.5-inch M28A2 HEAT rocket heads loaded with cast 65/35 HMX/TNT. These heads penetrated 15.9 ± 0.2 inches into mild steel targets, whereas similar heads loaded with Composition B, tested as control samples, penetrated 14.7 and 14.8 inches, respectively. These values indicate that an improvement of 8% was obtained by using octol. It was believed that even greater improvement might be achieved by using octols containing a larger proportion of HMX, but lack of HMX at that time prevented

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investigation of this possibility, or even additional testing to confirm the initial results.

2. In the following two years interest in HMX increased at the several establishments involved in the study of military explosives. This interest created a demand for substantial quantities of this explosive for experimental use.

Process studies were undertaken here and at Holston Ordnance Works to overcome difficulties in and improve the procedure for making HMX. At Holston the problem of making a castable octol of the highest possible HMX content without loss of pourability was attacked with the result that the know-how necessary to produce 75/25 octol having adequate fluidity at the temperatures used in melt-loading operations was acquired. The way was thus opened for the establishment in the 1954-55 period of facilities for producing the limited quantities of HMX and octol required for experimental purposes.

3. The receipt of 300 pounds of 75/25 octol from Holston Ordnance Works in July 1954 made possible resumption of the investigation of octols for use in shaped charge ammunition. This work was undertaken as part of an extensive program designed to evaluate HMX and HMX compositions for all sorts of military applications. Since the limited quantity of octol available was apportioned among several applications being studied simultaneously, the initial effort was limited to testing 75/25 and

70/30 octol in comparison with Composition B in the 3.5-inch T205E1 HEAT rocket head and the M31 HEAT rifle grenade used as test vehicles. The loaded heads were fired statically against mild steel targets. Subsequently as time and material permitted, tests were conducted with the following as test vehicles:

- 3.5-inch T205E-HEAT rocket head
- 90 mm T198E45 HEAT shell
- 2.75-inch M1 HEAT rocket head
- 3.5-inch M28A2 HEAT rocket head
- STRIM rifle grenade
- 90 mm T249E4 HEAT shell

4. The choice of test vehicles was governed to some extent by the availability of suitable metal parts and also by a desire to explore possible effects of light and heavy confinement, and shape and thickness of charge liner.

5. Another objective of some of the tests was to determine whether metal parts designs giving marginal performance with Composition B bursting charges would more nearly fulfill performance requirements if the bursting charge were made of octol. The results of these tests are included in this report to provide a complete record of the tests conducted here to date in which the octols have been involved.

RESULTS

6. The results of static firing tests of thirty 3.5-inch T205E1 HEAT rocket heads, ten each loaded with 75/25 octol,

70/30 octol, and Composition B, are presented in Table 1 (p 13). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composition B
Penetration, inches of mild steel			
Maximum	16.42	16.78	15.37
Minimum	14.16	14.22	13.00
Average	15.40	15.45	13.98
Std deviation	0.70	0.99	0.83

7. The results of static firing tests of thirty M31 HEAT rifle grenades, ten each loaded with 75/25 octol, 70/30 octol, and Composition B, are presented in Table 2 (p 14). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composition B
Penetration, inches of mild steel			
Maximum	14.05	13.43	12.39
Minimum	12.01	11.18	9.51
Average	13.00	12.66	11.70
Std deviation	0.64	0.67	0.95

8. The results of static firing tests of twenty 3.5-inch T205E-HEAT rocket heads, ten each loaded with 75/25 octol and Composition B, are presented in Table 3 (p 15). The following is a summary of the data:

Bursting Chg.	75/25 Octol	Composition B
Penetration, inches of mild steel		
Maximum	21.74	21.09
Minimum	19.43	15.23
Average	20.75	18.80
Std deviation	0.64	1.71

9. The results of static firing tests of thirty 90 mm T108E45 HEAT shell, ten each loaded with 75/25 octol, 70/30 octol, and Composition B, are presented in Table 4 (p 16). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composition B
Penetration inches of mild steel			
Maximum	16.26	15.17	15.19
Minimum	11.11	13.21	12.70
Average	14.84	14.36	13.75
Std. deviation	1.63	0.58	1.20

10. The results of static firing tests of thirty 2.75-inch M1 HEAT rocket heads, ten each loaded with 75/25 octol, 70/30 octol, and Composition B, are presented in Table 5 (p 17). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composition B
Penetration, inches of mild steel			
Maximum	12.80	12.69	12.14
Minimum	10.38	8.48	9.55
Average	11.45	11.83	10.97
Std. deviation	0.89	1.35	0.91

11. The results of static firing tests of thirty 3.5-inch M28A2 HEAT rocket heads, ten each loaded with 75/25 octol, 70/30 octol, and Composition B, are presented in Table 6 (p 18). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composi- tion B
---------------	----------------	----------------	--------------------

Penetration, inches
of mild steel

Maximum	16.30	18.21	16.82
Minimum	14.65	16.35	14.63
Average	15.63	17.28	15.99
Std. deviation	0.49	0.48	0.63

12. The results of static firing tests of thirty-seven 73 mm STRIM HEAT rifle grenade heads, twelve each loaded with 75/25 octol and Composition B, and thirteen loaded with 70/30 octol, are presented in Table 7 (p 19). The following is a summary of the data:

Bursting Chg.	75/25 Octol	70/30 Octol	Composi- tion B
---------------	----------------	----------------	--------------------

Penetration, inches
of mild steel

Maximum	17.5	18.0	16.1
Minimum	10.4	9.0	8.6
Average	14.6	15.6	13.3
Std. deviation	2.1	2.5	2.2

13. The results of static firing tests of twenty 90 mm T249E4 HEAT shell, ten each loaded with 70/30 octol and Composition B, are presented in Table 8 (p 20). The following is a summary of the data:

Bursting Chg.	70/30 Octol	Composition B
---------------	-------------	---------------

Penetration, inches
of mild steel

Maximum	16.99	15.14
Minimum	16.04	11.86
Average	16.48	13.74
Std deviation	0.31	1.12

DISCUSSION OF RESULTS

14. Control samples consisting of test vehicles from the same lot loaded with Composition B were included in each series of firing tests to provide a basis for a direct comparison of the performance of the octols with that of Composition B under the same test conditions. The decision to evaluate the octols for use in HEAT ammunition by comparison with Composition B rather than with the corresponding 70/30 and 75/25 cyclotols was based on the fact that Composition B is the present standard explosive filler for this type of ammunition and the fact that 70/30 cyclotol performed no better than Composition B, and 75/25 cyclotol only very slightly better, in the comparative steel penetration tests reported in Reference 1.

15. At the beginning of this investigation it seemed apparent from the results of the earlier tests that HMX/TNT mixtures are more effective in HEAT ammunition, volume for volume, than the corresponding RDX/TNT mixtures. Since the improvement stems from the greater detonation pressure of HMX, increasing the proportion of HMX in octol to the maximum that can be used and still retain pourability in melt-loading operations should yield the most effective explosive for this type of ammunition. The selection of 75/25 octol for study was based on this reasoning. 70/30 octol was included to show the effect of reducing the proportion of HMX 5% if this ever appeared desirable to facilitate loading. It was

anticipated from experience with 75/25 cyclotol that occasionally 75/25 octol would be too viscous in the molten state for satisfactory loading into HEAT ammunition by ordinary production methods, and it would be advisable to use the less viscous 70/30 octol to avoid this difficulty. Other considerations were the lower material cost of 70/30 octol, the probability that it could be produced with less effort than can low-viscosity 75/25 octol, and the possibility, in view of the excellent performance of 65/35 octol in the earlier tests, that the performance of 70/30 octol would be virtually equivalent to that of 75/25 octol.

16. Examination of the results of the first three series of tests, those in which the T205E1 rocket head, the M31 rifle grenade head, and the T205E rocket head were the test media, shows that the whole level of performance of the octols in terms of inches of mild steel penetrated was significantly higher than that of Composition B. This is clearly evident from the summaries of the data given in the "Results" section, which show that not only the average but also the maximum and minimum values are higher.

17. The order of difference between the performance of the octols and of Composition B in the first three series of tests can be found easily by calculating from the average penetration values a numerical rating for each explosive in each test series based on rating the performance of Composition B as 100. The ratings thus obtained are:

Test Series No.	Performance Ratings		
	Composi- tion B	70/30 Octol	75/25 Octol
1	100	110.5	110.2
2	100	108.2	111.1
3	100	—	110.4

These ratings show that in each of the three test media replacement of Composition B with 75/25 octol resulted in 10 to 11% improvement in performance, and replacement with 70/30 octol gave 8 to 10% improvement.

18. Comparison of the results of the first series of tests with those of the third series shows that combining the improvement to be gained by use of the octols in place of Composition B with that to be gained by use of a trumpet-shaped, or "double-angle" charge liner in place of a conical liner would result in a very large improvement in the performance of some items of ammunition, possibly nearly 50%. This comparison is valid since the third series differs from the first mainly in that the charge liner in the first was conical whereas in the third it was trumpet-shaped. 70/30 octol was omitted from the third series because of a shortage of test vehicles. The more important pertinent data are:

Bursting Chg Series	75/25 Octol		Composition B	
	1st	3rd	1st	3rd
Penetration, in. of mild steel				
Maximum	16.42	21.74	15.37	21.09
Minimum	14.16	19.43	13.00	15.23
Average	15.40	20.75	13.98	18.80

The difference between 13.98 and 20.75 is the overall improvement gained by changing both the explosive and the liner. This is a gain of 48.4%. The improvement resulting from changing the liner only is the difference between 13.98% and 18.80%, or between 15.40% and 20.75%, gains of 34.5% and 34.7%, respectively.

19. Examination of the results of the fourth, fifth, and sixth series of tests, those in which the 90 mm T108E45 shell, the 2.75-inch M1 rocket head, and the 3.5-inch M28A2 rocket head were the test media, shows that the superiority of the octol-loaded ammunition was less pronounced in these series than in the first three series. In all but the tests of 75/25 octol in the M28A2 rocket head the octols performed better than did Composition B, but the levels of performance varied from one series to another and were generally lower than in the first three series. This is reflected in the following performance ratings based on average penetration values:

Test Series No.	Test Vehicle	Performance Rating Composition B	Performance Ratings	
			70/30 Octol	75/25 Octol
4	T108E45 shell	100	104.4	107.9
5	M1 rocket head	100	107.8	104.4
6	M28A2 rocket head	100	108.1	97.8

20. The reasons for the poorer showing of the octols in the fourth, fifth, and sixth series of tests are unknown, but they are thought to reside in the test specimens themselves rather than in

the testing procedure. The low average penetration value obtained in the fourth series in the tests of 70/30 octol is particularly puzzling since the spread in results in this group of tests was not large. The inferior performance of 75/25 octol in the M1 and M28A2 rocket heads is attributed in part to imperfections in the bursting charges resulting from loading difficulties. At the time these heads were loaded the supply of comparatively low-viscosity 75/25 octol used in the earlier series was exhausted. When the heads were loaded with the high-viscosity material on hand, difficulty was experienced in trying to meet standards set for acceptable quality bursting charges. Reliance was placed on radiographs to show imperfections, and the heads were unloaded and reloaded until charges of acceptable quality were obtained. The fact that little difficulty was encountered in loading the M1 and M28A2 heads with 70/30 octol is believed to be reflected in the somewhat superior performance of this explosive in these test media, but even here the performance level was lower than was expected.

21. The seventh and eighth series of tests were conducted in the course of design studies directed toward the development of specific ammunition designs. In the seventh series the objective was to evaluate the performance of the octols and Composition B in a small light-weight body containing a trumpet-shaped copper charge liner as an approach to designing a more effective rifle grenade. The French STRIM grenade head was used as the test

vehicle as parts on hand offered the opportunity of testing the desired combination without having to manufacture metal parts. In this series as in the previous series the level of performance of the octols was substantially higher than that of Composition B.

22. Especially noteworthy among the data obtained in the tests of the octols in the seventh series are the numerous values in the range of 16 to 18 inches, which, for a head of this caliber, is considered remarkably good performance. These values indicate the potential performance of the octol-trumpet-shaped liner combination is high and merits much more extensive investigation. Examination of the individual test data shows that interspersed among the apparently normal high values are several very low values which tended to depress the average values so that they do not show the true level of performance of which the octols are capable. These low values are definitely abnormal, since multiple holes were observed in the target, indicating the formation of double- and triple-forked jets in each test in which the penetration was poor. This erratic behavior is believed to stem from imperfections in the test vehicles or damage to the charge liners by sand blasting done by mistake during the renovation of the metal parts before they were loaded. Despite the effect of these abnormal low results on the average penetration values, the performance of the octols exceeded that of Composition B by a considerable margin. This is evident from the following performance ratings:

Test Series No.	Performance Ratings		
	Composition B	70/30 Octol	75/25 Octol
7	100	117.3	109.8

23. The eighth series of tests was conducted to determine whether the effectiveness of a light aluminum HEAT shell being considered for the 90 mm PAT weapon would be increased substantially by use of a 70/30 octol bursting charge in place of a Composition B charge. 70/30 octol was chosen in preference to 75/25 octol for this series of tests because of its lower viscosity and its good performance in the STRIM grenade. It was expected that the higher viscosity of 75/25 octol would make attainment of good charge quality in this shell difficult because of the small filling hole. The high level of performance of 70/30 octol as compared with that of Composition B in this test series is especially noteworthy. The results in the tests of 70/30 octol were also remarkably uniform. Calculation of performance ratings from the average penetration values resulted in the following figures:

Test Series No.	Performance Ratings	
	Composition B	70/30 Octol
8	100	119.9

24. It may be noted that the tables of results contain the weights of the loaded test specimens and the weights of the bursting charges they contained. These data are included mainly to record the information and to show that replacement of Composition B with the octols increases the weight of the explosive charge in the shell, head, or grenade, but changes the

overall weight of the loaded item only slightly. The increase in weight stems from the differences in the specific gravity of the three explosives. For charges cast in ammunition of this type the overall specific gravity of 75/25 octol is normally about 1.81, of 70/30 octol about 1.79, and of Composition B about 1.69.

EXPERIMENTAL PROCEDURE

25. The Test Vehicles. With the exception of the STRIM rifle grenade heads and the 90 mm T249E4 HEAT Shell the metal parts assemblies used in the preparation of the test specimens were taken from excess stock on hand at the Arsenal or from lots of material being used at the time in the production of ammunition. It is considered that the test vehicles used were representative of the quality of metal parts assemblies normally used in HEAT ammunition. Where known, the lot numbers of these assemblies are given in the footnotes on the tables of results. The STRIM rifle grenade heads were obtained by disassembly and unloading by "steaming out" of French HEAT rifle grenades. The 90 mm T249E4 HEAT shell were modified shell prepared especially for these and other local tests. The regular T249E4 aluminum bodies were modified by undercutting the interior surface at the forward end to provide a cylindrical cavity $3.165 \pm .005$ inches in diameter by $1.556 \pm .020$ inch deep. The copper liners assembled into the modified bodies were of 0.075-inch wall thickness and of the straight conical design used in the 3.5-inch T205 E1 HEAT rocket head. Assembled to the

bodies were the standard T249E4 shell ogive complete with spike but without the "lucky".

26. Loading the Test Vehicles. The 75/25 octol used in the test specimens for the first four series of tests was from Lot HOL-86-21, produced at Holston Ordnance Works in July 1954. The 70/30 octol used in all series of tests and the 75/25 octol used in loading test vehicles for all but the first four series were prepared locally from HMX and TNT. The Composition B used was low-viscosity material, manufactured at Holston Ordnance Works, and was representative of the material being used in the regular production of HEAT ammunition. The metal parts assemblies were melt-loaded by methods currently used successfully for loading this type of ammunition with Composition B, except that (a) the assemblies were preheated to about 95°C to facilitate flow of the octols around the base of the charge liners, and (b) the pouring temperature for the octols was 90-95°C. When necessary the riser was caused to stay molten longer by heating the explosive with a steam-heated "finger" inserted into the neck of the pouring funnel. The dimensions of the bursting charges and fuze cavities were those specified on current loading assembly drawings for the shell, grenade, or head. In the STRIM heads the dimensions of the bursting charge and booster cavity present in the original French heads were duplicated.

27. Firing Test Procedures. Common

to all series of tests was the use of stacks of 5" x 5" x 1" or 4" x 4" x 1" mild steel plates for targets and of an electric blasting cap for initiating detonation in the fuze assembly. After each shot the number of plates perforated was determined by counting and the plate partially penetrated was saved for subsequent measurement of the distance the jet had traveled in it. The depth of penetration reported is the sum of this fraction of an inch and the number of plates perforated. Prior to firing, the test specimen with booster charge and blasting cap assembled was supported in a vertical position on the top of the target by snug-fitting, heavy-walled cardboard tubes arranged to hold the base of the charge liner at a known fixed distance from the target (called the standoff). Information pertinent to the individual series of tests is as follows:

First Series. The loaded 3.5-inch T205E1 rocket heads were assembled with cardboard standoff tubes, which were taped in position so that the overall length from the rear end of the head to the far end of the tube was 13 $\frac{5}{8}$ inches, which is the length of the standard head loading assembly with the aluminum fuze cover assembled. The head-tube assembly was placed on top of a stack of twenty mild steel plates, the five plates at the top of the stack being 5" x 5" x 1" and the remaining fifteen 4" x 4" x 1". The heads were fired by improvised fuzes placed in the fuze cavity. The fuze contained a 27.6-gram booster pellet, 1.305" diameter x 0.732"

high, density 1.72g/cc, made of 97/3 HMX/Stanolind Wax. The pellet was centered in the fuze cavity by a cardboard sleeve. It was detonated by a U. S. Army Special Blasting Cap, which butted against the center of the pellet.

Second Series. The loaded M31 rifle grenades were assembled with cardboard standoff tubes, which were taped in position so that the overall length of the grenade-tube assembly was 9 $\frac{1}{4}$ inches, which is the length of the standard loading assembly. The grenade-tube assembly was placed on top of a stack of fifteen 4" x 4" x 1" mild steel plates. The grenades were fired by improvised fuzes placed in the fuze cavity. The fuze contained a 7.2-gram tetryl booster pellet, 0.799" diameter x 0.55" high, density 1.59 g/cc. The pellet was centered in the fuze cavity by two or three layers of adhesive tape wrapped around the periphery. It was detonated by a U. S. Army Special Blasting Cap, which butted against the center of the booster pellet and was held in this position by a wooden detonator holder.

Third Series. The loaded 3.5-inch T205E-rocket heads were assembled with cardboard standoff tubes, which were taped in position so that the overall length of the head tube assembly was 13 $\frac{1}{4}$ inches. The head-tube assembly was placed on top of a stack of twenty-three mild steel plates, the top five plates being 5" x 5" x 1" and the remaining eighteen 4" x 4" x 1". The heads were fired by improvised fuzes placed in the fuze cavity. The fuze

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contained an 8-gram tetryl booster pellet, 1.05" diameter \times 0.37" high. The pellet was centered in the fuze cavity by wrappings of adhesive tape. The booster pellet was detonated by a U. S. Army Special Blasting Cap inserted through a small hole in the metal plug used as closure for the rear end of the heads.

Fourth Series. The loaded 90 mm T108E45 HEAT shell were assembled with cardboard standoff tubes, which were taped in position so that the overall length of the shell-tube assembly was $18\frac{3}{4}$ inches. This assembly was placed on top of a stack of twenty mild steel plates, the top two plates being 6" \times 6" \times 1" and the remaining eighteen 5" \times 5" \times 1". The shell were fired by improvised fuzes inserted in the fuze cavity. Each fuze contained a 1.248" diameter \times 1.00" high booster pellet, density 1.76 g/cc, weighing about 25.5 grams. The pellet, which was made of 97/3 HMX/Stanolind Wax, was detonated by a U. S. Army Special Blasting Cap.

Fifth Series. The loaded 2.75 inch M1 HEAT rocket heads were assembled with cardboard standoff tubes which were taped in position so that the overall length of the head-tube assemblies was 11 inches. The head-tube assembly was placed on top of a stack of fifteen 4" \times 4" \times 1", or 5" \times 5" \times 1", mild steel plates. The loaded heads contained the 14.4-gram tetryl booster pellet and the felt filler disc specified

on Loading Assembly Drawing 82-16-40 dated 1 March 1954, and were assembled with the standard adapter closure used on this shell. Access to the booster pellet was provided by drilling a hole in the rear end of the adapter and the felt disc prior to assembling them. The shell were fired by a U. S. Army Special Blasting Cap inserted through this hole so that it contacted the center of the rear face of the booster pellet.

Sixth Series. The loaded heads were assembled with cardboard tubes positioned so as to support the heads in a vertical position with the nose end of the ogive resting on the target. The targets were stacks of twenty 5" \times 5" \times 1" mild steel plates. Tetryl booster pellets, 1.43" diameter \times 0.50" high, weighing 17.5 grams, were placed in the fuze cavity. The heads were fired by U. S. Army Special Blasting Caps butting against the center of the booster pellets.

Seventh Series. The reloaded 73 mm STRIM rifle grenades were assembled with cardboard tubes positioned so as to support the grenades in a vertical position with the nose end of the ogive in contact with the target. The targets were stacks of twenty 5" \times 5" \times 1" mild steel plates. The booster cavity in the bursting charge of each grenade was filled with a 10.2-gram rounded-bottom booster pellet made of desensitized RDX (approximately 92.5/6.6/0.9 RDX/wax/graphite). These pellets were obtained from the original French grenades when they were disassembled.

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A rounded-bottom detonator, also recovered from the original grenades, was placed in the recess provided in the booster pellet. The grenades were fired by commercial No. 6 blasting caps held in a vertical position in contact with the rounded-bottom detonators resting in the booster pellets.

Eighth Series. The loaded 90 mm T249E5 HEAT shell complete with nose spike (minus the lucky fuze element) were supported in a vertical position with the end of the spike resting on the targets. Each target was a stack of twenty 5" x 5" x 1" mild steel plates. The fuze

cavity of the shell contained an improvised fuze consisting of a cylindrical wooden block having a recess at the forward end in which there was a 7.6-gram RDX booster pellet, 0.99" diameter x 0.8" high, and a central channel in which there was a U. S. Army Special Blasting Cap.

REFERENCE

L. Jablansky, *Evaluation of 70/30 Cyclotol and 75/25 Cyclotol for Use in HE and HEAT Projectiles*, Picatinny Arsenal Technical Report 1944, 25 August 1953

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TABLE 1

Results of Firing Tests of 3.5-Inch T205E1 Rocket Heads*

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Head Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	1.71	3.67	15.88
2	"	1.70	3.63	14.92
3	"	1.71	3.70	15.18
4	"	1.72	3.65	14.16
5	"	1.70	3.66	16.13
6	"	1.71	3.67	15.04
7	"	1.71	3.65	15.97
8	"	1.69	3.64	16.42
9	"	1.72	3.67	15.54
10	"	1.71	3.65	14.78
			Average	15.40
11	70/30 Octol	1.69	3.65	13.60
12	"	1.68	3.61	15.52
13	"	1.67	3.61	14.22
14	"	1.69	3.65	15.61
15	"	1.69	3.65	16.18
16	"	1.65	3.55	16.03
17	"	1.67	3.67	14.73
18	"	1.67	3.65	16.78
19	"	1.68	3.59	16.38
20	"	1.69	3.65	15.46
			Average	15.45
21	Composition B	1.59	3.54	15.37
22	"	1.59	3.54	14.87
23	"	1.60	3.56	14.48
24	"	1.59	3.53	13.48
25	"	1.61	3.58	13.20
26	"	1.60	3.61	13.80
27	"	1.59	3.57	13.00
28	"	1.60	3.54	14.76
29	"	1.60	3.60	13.81
30	"	1.60	3.51	13.07
			Average	13.98

*Metal parts assemblies of Lot HBI-1-6 manufactured in October 1953

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TABLE 2
Results of Firing Tests of M31 HEAT Rifle Grenades*

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Grenade Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	.63	1.21	12.40
2	"	.64	1.23	12.01
3	"	.64	1.23	13.35
4	"	.63	1.21	13.16
5	"	.65	1.23	12.26
6	"	.63	1.21	13.06
7	"	.64	1.22	14.05
8	"	.65	1.22	13.32
9	"	.65	1.23	13.64
10	"	.64	1.22	12.76
			Average	13.00
11	70/30 Octol	.64	1.22	12.81
12	"	.64	1.22	13.11
13	"	.64	1.22	13.43
14	"	.63	1.22	11.78
15	"	.63	1.21	11.18
16	"	.63	1.21	13.01
17	"	.63	1.21	12.55
18	"	.64	1.22	12.79
19	"	.64	1.22	12.98
20	"	.64	1.22	12.92
			Average	12.66
21	Composition B	.60	1.17	12.61
22	"	.60	1.19	10.63
23	"	.60	1.19	11.50
24	"	.60	1.17	12.39
25	"	.59	1.16	12.14
26	"	.60	1.19	9.51
27	"	.60	1.18	12.26
28	"	.61	1.20	12.16
29	"	.59	1.18	12.05
30	"	.60	1.17	11.76
			Average	11.70

*Metal parts assemblies of Lot MXL-1-5

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TABLE 3

Results of Firing Tests of 3.5-Inch T205E-Rocket Heads*

Test No.	Bursting Charge Explosive	Weight, lb	Loded Head Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	1.76	3.55	19.43
2	"	1.81	3.56	21.16
3	"	1.76	3.53	20.91
4	"	1.77	3.52	20.32
5	"	1.75	3.53	20.43
6	"	1.74	3.49	21.17
7	"	1.77	3.52	20.18
8	"	1.77	3.54	21.14
9	"	1.75	3.53	21.74
10	"	1.75	3.52	21.04
Average				20.75
11	Composition B	1.64	3.40	19.09
12	"	1.64	3.44	19.88
13	"	1.63	3.43	15.23
14	"	1.65	3.41	19.11
15	"	1.65	3.41	17.92
16	"	1.63	3.41	16.86
17	"	1.65	3.43	18.93
18	"	1.66	3.40	19.88
19	"	1.66	3.42	21.09**
20	"	1.66	3.42	19.96
Average				18.80

*Metal parts assemblies of Lot CQMI-1-1954

**Jet came out side of target in 20th plate, cut through edge of 21st plate and stopped in edge of 22nd plate. High value obtained in this test probably resulted from path of jet being too close to edge of target.

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TABLE 4
Results of Firing Tests of 90 mm T108E45 HEAT Shell*

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Shell Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	2.14	11.58	16.07
2	"	2.10	11.72	12.99
3	"	2.10	11.71	11.11
4	"	2.08	11.66	15.31
5	"	2.08	11.71	15.00
6	"	2.02	11.85	16.26
7	"	2.09	11.76	15.24
8	"	2.07	11.63	14.47
9	"	2.09	11.69	16.18
10	"	2.10	11.69	15.75
Average				14.84
11	70/30 Octol	2.06	11.67	13.84
12	"	2.02	11.70	14.42
13	"	2.05	11.56	15.17
14	"	2.08	11.65	none**
15	"	2.07	11.52	14.83
16	"	2.12	11.60	13.21
17	"	2.07	11.68	14.78
18	"	2.10	11.59	14.51
19	"	2.10	11.59	14.39
20	"	2.09	11.59	14.10
Average				14.36
21	Composition B	1.96	11.53	13.29
22	"	1.95	11.57	13.18
23	"	1.93	11.60	13.88
24	"	1.96	11.54	12.70
25	"	1.95	11.59	14.64
26	"	1.96	11.60	14.60
27	"	1.99	11.63	14.74
28	"	1.98	11.54	15.19
29	"	1.97	11.56	14.06
30	"	1.98	11.56	11.17
Average				13.75

*Metal parts assemblies of Lot PM1-4

**Omitted from the average

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TABLE 5

Results of Firing Tests of 2.75-Inch M1 HEAT Rocket Heads

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Shell Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	.92	4.68	10.38
2	"	.93	4.69	12.64
3	"	.93	4.67	10.78
4	"	.92	4.67	11.20
5	"	.91	4.67	12.47
6	"	.94	4.68	11.38
7	"	.92	4.68	11.47
8	"	.93	4.69	12.80
9	"	.93	4.68	10.93
10	"	.94	4.67	10.46
Average				11.45
11	70/30 Octol	.92	4.67	11.19
12	"	.93	4.69	8.48
13	"	.94	4.69	13.16
14	"	.93	4.68	12.05
15	"	.92	4.66	13.03
16	"	.93	4.67	12.65
17	"	.94	4.70	12.69
18	"	.93	4.67	11.48
19	"	.94	4.68	11.66
20	"	.93	4.67	11.87
Average				11.83
21	Composition B	.87	4.63	9.55
22	"	.88	4.64	11.88
23	"	.87	4.62	10.95
24	"	.87	4.63	10.40
25	"	.85	4.55	9.91
26	"	.87	4.63	10.53
27	"	.89	4.62	11.27
28	"	.87	4.63	12.14
29	"	.87	4.62	11.38
30	"	.88	4.62	11.72
Average				10.97

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TABLE 6

Results of Firing Tests of 3.5-Inch M28A2 Rocket Heads*

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Head Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	2.07	4.68	15.57
2	"	2.09	4.66	15.40
3	"	2.03	4.74	15.10
4	"	2.07	4.66	15.87
5	"	2.08	4.65	15.87
6	"	2.09	4.67	15.77
7	"	2.09	4.67	16.30
8	"	2.10	4.65	15.57
9	"	2.04	4.70	16.20
10	"	2.09	4.68	14.65
Average				15.63
11	70/30 Octol	2.01	4.62	16.35
12	"	1.99	4.70	17.57
13	"	1.99	4.67	17.15
14	"	1.99	4.70	17.09
15	"	1.99	4.70	18.21
16	"	2.00	4.65	17.42
17	"	1.98	4.68	17.10
18	"	2.01	4.69	17.48
19	"	2.00	4.63	17.53
20	"	2.00	4.63	16.94
Average				17.28
21	Composition B	1.86	4.52	14.63
22	"	1.86	4.52	16.82
23	"	1.86	4.55	15.87
24	"	1.86	4.51	16.10
25	"	1.85	4.53	15.80
26	"	1.86	4.55	15.73
27	"	1.86	4.52	16.14
28	"	1.86	4.53	16.37
29	"	1.86	4.50	15.67
30	"	1.87	4.54	16.79
Average				15.99

*Metal parts assemblies of Lot OD3-19-1-54

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TABLE 7

Results of Firing Tests of 73 mm STRIM Rifle Grenade Heads

Test No.	Bursting Charge Explosive	Weight, lb	Loaded Head Weight, lb	Penetration of Jet into Steel Target, in.
1	75/25 Octol	.77	1.49	16.8
2	"	.78	1.49	13.0
3	"	.78	1.49	10.4*
4	"	.77	1.49	15.4
5	"	.78	1.49	17.1
6	"	.78	1.49	17.3
7	"	.78	1.49	17.5
8	"	.78	1.49	10.9*
9	"	.77	1.49	15.0*
10	"	.78	1.49	10.8*
11	"	.78	1.49	16.1
12	"	.78	1.49	15.3*
Average				14.6
13	70/30 Octol	.76	1.48	18.0
14	"	.77	1.48	15.7
15	"	.77	1.48	16.3
16	"	.77	1.48	12.9*
17	"	.77	1.48	15.7
18	"	.77	1.48	9.0*
19	"	.78	1.49	17.2
20	"	.76	1.48	15.1
21	"	.77	1.48	17.0
22	"	.76	1.48	16.8
23	"	.77	1.48	18.0
24	"	.77	1.48	14.4*
25	"	.76	1.48	17.2
Average				15.6
26	Composition B	.72	1.44	15.1
27	"	.72	1.44	14.5
28	"	.73	1.45	8.6*
29	"	.72	1.44	16.1
30	"	.72	1.44	14.5
31	"	.72	1.44	11.6
32	"	.73	1.44	14.0
33	"	.73	1.44	15.5
34	"	.73	1.44	8.9*
35	"	.72	1.44	14.6
36	"	.73	1.44	13.0*
37	"	.73	1.44	13.5
Average				13.3

*Evidence of double or triple jets observed on examination of target

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TABLE 8

Results of Firing Tests of 90 mm T249E4 HEAT Shell

Test No.	Bursting Charge		Loaded Head Weight, lb	Penetration of Jet into Steel Target, in.
	Explosive	Weight, lb		
1	70/30 Octol	1.87	5.50	16.66
2	"	1.86	5.45	16.53
3	"	1.88	5.46	16.99
4	"	1.87	5.47	16.56
5	"	1.87	5.47	16.06
6	"	1.88	5.46	16.13
7	"	1.87	5.43	16.59
8	"	1.88	5.46	16.67
9	"	1.89	5.44	16.04
10	"	1.88	5.45	16.53
Average				16.48
11	Composition B	1.77	5.33	0*
12	"	1.74	5.34	15.14
13	"	1.74	5.33	14.54
14	"	1.75	5.31	14.62
15	"	1.74	5.33	14.11
16	"	1.73	5.32	12.08
17	"	1.73	5.34	14.16
18	"	1.75	5.34	11.86
19	"	1.74	5.39	13.73
20	"	1.74	5.33	13.45
Average				13.74

*Low-order detonation of bursting charge resulted from blasting cap being separated from booster pellet by half-inch air gap by mistake. Result disregarded in computing average.

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